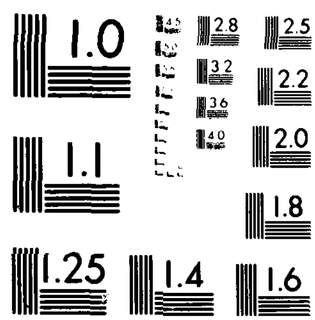
AD-A089 287   ANALYTICS INC WILLOW GROVE PA   F/G 15/3
A GENERALIZED AUTOMATED DECISION ALGORITHM FOR THE AEW ENGAGEME--ETC(U)
JUL 80   J HOPSON, S STARK, D DETWILER   N62269-79-C-0235
UNCLASSIFIED   NADC-80104-50   NL

END
DATE
FILMED
10 80
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

LEVEL II

REPORT NO. NADC-80104-50

AD A089287

A GENERALIZED AUTOMATED DECISION ALGORITHM FOR THE AEW ENGAGEMENT/INTERCEPT PLANNING FUNCTION

J. HOPSON, PhD
Aircraft and Crew Systems Technology Directorate
S. STARK
Software & Computer Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

D. DETWILER, W. ZACHARY, PhD & S. FITZKEE
ANALYTICS INCORPORATED
Jenkintown, Pennsylvania 19046

15 JULY 1980

FINAL REPORT

AIRTASK 3600000/001B/9F21-200-000
AIRTASK A035-3400/001B/WF57-525-000

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy
Washington, D. C. 20361

NOTICES

REPORT NUMBERING SYSTEM - The numbering of technical project reports issued by the Naval Air Development Center is arranged for specific identification purposes. Each number consists of the Center acronym, the calendar year in which the number was assigned, the sequence number of the report within the specific calendar year, and the official 2-digit correspondence code of the Command Office or the Functional Directorate responsible for the report. For example: Report No. NADC-78015-20 indicates the fifteenth Center report for the year 1978, and prepared by the Systems Directorate. The numerical codes are as follows:

CODE	OFFICE OR DIRECTORATE
00	Commander, Naval Air Development Center
01	Technical Director, Naval Air Development Center
02	Comptroller
10	Directorate Command Projects
20	Systems Directorate
30	Sensors & Avionics Technology Directorate
40	Communication & Navigation Technology Directorate
50	Software Computer Directorate
60	Aircraft & Crew Systems Technology Directorate
70	Planning Assessment Resources
80	Engineering Support Group

PRODUCT ENDORSEMENT - The discussion or instructions concerning commercial products herein do not constitute an endorsement by the Government nor do they convey or imply the license or right to use such products.

APPROVED BY: [illegible] DATE: 8/25/80

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(19) REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: (18) NADC/80104-50

2. GOVT ACCESSION NO.: AD-A089 287

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): A Generalized Automated Decision Algorithm For The AEW Engagement/Intercept Planning Function,

5. TYPE OF REPORT & PERIOD COVERED: (9) Final

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): Julie/Hopson [redacted] Steve/Stark - Naval Air Development Center; Dave/Detwiler, Wayne/Zachary [redacted] Steve/Fitzkee ~~- Analytics Incorporated~~

8. CONTRACT OR GRANT NUMBER(s): (15) N62269-79-C-0235

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Air Development Center, Warminster, PA 18974

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AIRTASK 3600000/001B/9F21-200-000; AIRTASK A035-3400/001B/WF57-525-000

11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Air Systems Command, Department of the Navy, Washington, DC 20360

12. REPORT DATE: 15 Jul [redacted] 80

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

16) F[illegible] F5[illegible]525

17) WF[illegible] WF57[illegible]

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Artificial Intelligence	Decision Analysis	Decision Aiding Techniques
Decision Aids	Decision Augmentation	AEW
Decision Automation	Decision Support Systems	Supervisory Control
Many on Many	Automation Process Systems	Automated Assisted Systems

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document describes a generalized automated decision algorithm for the Engagement/Intercept Planning Function of an AEW (Airborne Early Warning) aircraft in the post-1985 time frame. Structure of the automated algorithm was based upon an analysis of the decision situation which included identification of relevant decision processes and required data inputs/outputs in order to allocate man/machine functions. Individual decision processes were categorized and matched to appropriate modeling techniques which were inte-

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

UNCLASSIFIED 405 904

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) grated into a complex algorithmic network to automate major functions of the Engagement/Intercept Plan.

NADC-80104-50

NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PENNSYLVANIA 18974

A GENERALIZED AUTOMATED DECISION ALGORITHM FOR THE AEW ENGAGEMENT/INTERCEPT PLANNING FUNCTION

15 JULY 1980

ACKNOWLEDGEMENTS

The contributions of M. STRIEB and C. CAMPO of the Analytics Corporation under Naval Air Development Center Contract No. N62269-79-C-0325 and CDR N. LANE and I. BELLEW of Naval Air Development Center are gratefully acknowledged and appreciated.

EXECUTIVE SUMMARY

This document describes a generalized automated decision algorithm for the Engagement/Intercept Planning function of an AEW (Airborne Early Warning) aircraft in the post-1985 time frame. Structure of the automated algorithm was based upon an analysis of the decision situation which included identification of relevant decision processes and required data inputs/outputs in order to allocate man/machine functions. Individual decision processes were categorized and matched to appropriate modeling techniques which were integrated into a complex algorithmic network to automate major functions of the Engagement/Intercept Plan.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

1. BACKGROUND

1.1 INTRODUCTION

Airborne Early Warning (AEW) missions in the post-1985 time frame will be performed with a new generation of platforms incorporating new or modified command and control systems. These missions will demand more rapid, precise, and correct responses to a threat projected to consist of waves of high speed aircraft, and high and low altitude missiles launched from aircraft, ships, and submarines. The detection and response times for AEW systems will thus be limited and mission critical.

Advanced AEW systems will increase the information processing load for the operator and reduce the time for tactical response. To meet these systems demands, functions now performed by the human decision maker will need to be modified. Many integration and control decisions performed manually using present systems will require decision automata. Automated systems will need to be developed to optimize man/machine performance to satisfy operational mission requirements for time-critical decision paths. Man will be removed from the routine decision loop and assume the role of a system monitor with executive control override as shown in Figure 1-1. Although future AEW systems are relatively unstructured at this time, systematic methods will need to be developed to analyze and structure future needs to assure optimized function allocation, appropriate architecture, and hardware/software integration requirements.

1.2 PROGRAM OBJECTIVE

Development of decision automata for AEW applications is well within the state-of-the-art. Microprocessing hardware, Large Scale Integration (LSI), and Very High Speed Integration (VHSI) technologies will be well advanced in the 1985-2000 year time frame. Tactical decision aid technologies are now being developed for application to aircraft on-board data processing needs. General-purpose decision algorithms have already been developed and tested which can be applied to solving future time-critical, multi-dimensional tactical decision problems. The objective of this program is to analyze operator decision processes to generate requirements for automatic decision algorithm solutions addressed to a selected critical airborne command and control decision problem. These requirements can then be used to develop a prototype decision automata which can be tested against a human operator in a computerized simulation facility.

1.3 APPROACH

The top-down approach being used to accomplish the program objectives is outlined in Figure 1-2. The first two steps, determination of platform function/mission requirements and specification of performance objectives, simply clarify and structure the arena of potential decision automata. The third step, identification of problem areas, defines the functional decision making niches that each of the potential automata may occupy. The range of

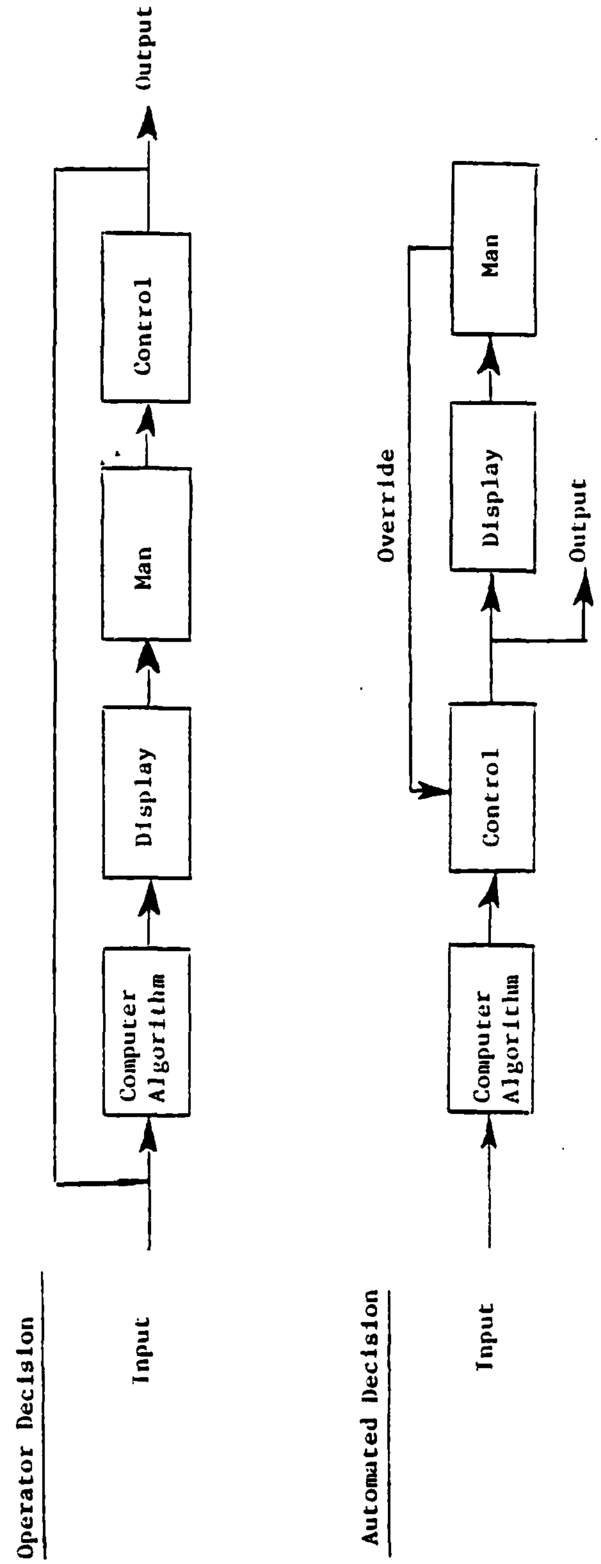


Figure 1-1. Operator Decision Vs. Automated Decision

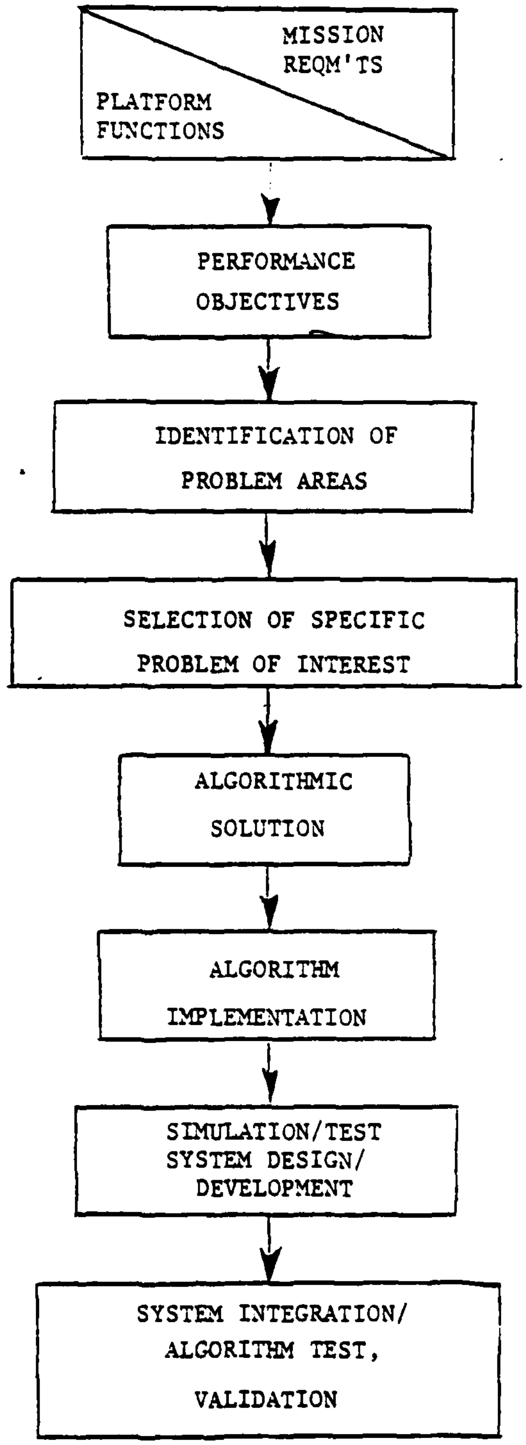


Figure 1-2. Approach

potential automata thus identified is narrowed to a single case in the fourth step, allowing the development, implementation and testing to be properly focused. Algorithmic solution requires an intensive analysis effort to describe the selected problem in detail and then find suitable techniques to solve it. At this point, an algorithm can be implemented and eventually integrated with a simulation/test system.

1.4 ACCOMPLISHMENTS/DOCUMENT OVERVIEW

A previous paper (reference 6) reported on program progress up to and including the selection of a specific problem area of interest. This document incorporates the earlier paper and reviews all program accomplishments to date which extend through the formulation of a generalized automated Engagement/Intercept Planning decision algorithm. Section 2 discusses the endeavor leading to the selection of the Engagement/Intercept Planning function problem area. It includes determination of the mission requirements/platform functions and performance objectives, identification of AEW problem areas, and a description of the selection process. Sections 3 and 4 are devoted to a generalized algorithmic solution of the chosen problem. A methodology, which describes decision functions in detail and associates appropriate decision automation techniques, is applied to the Engagement/Intercept Planning function in Section 3. The results of this decision analysis are then used in Section 4 to construct a generalized automated Engagement/Intercept Planning algorithm. Section 5 presents current conclusions on the status of the effort.

2. INITIAL EFFORTS

2.1 DETERMINATION OF AEW MISSION REQUIREMENTS/PLATFORM FUNCTIONS AND PERFORMANCE OBJECTIVES

Three sources of information were utilized to familiarize the study team with the AEW mission: review of relevant documentation, observation of an in-service AEW system, and utilization of study team technical and operational experience.

Documentation reviewed included V/STOL-A Avionics Functional Description (produced by the NAVAIRDEVCEN Center Design Team), the V/STOL-A Functional Partitioning Effort, the E-2C NATOPS Manual, and Naval Warfare Publications (NWP) 1 and 55. These documents are listed as references 1 through 5.

The study team travelled to Naval Air Station, Norfolk, VA to observe the E-2C weapons systems simulator facility. This visit congealled many of the thoughts gleaned from the documentation and provided the opportunity to discuss the mission with fleet experienced personnel.

2.1.1 THE ROLE OF THE AEW IN NAVAL WARFARE

The AEW aircraft is a multiple-mission, multiple-role platform. Its extensive array of sensors and communications equipment is useful to all warfare coordinators in the conduct of their tasks. AEW mission responsibilities include:

- Early Warning
- Air Intercept Control
- Surface/Subsurface Surveillance Coordination (SSSC)
- Strike Coordination
- Electronic Warfare
- Search and Rescue (SAR), and
- Air Traffic Control

These AEW missions fulfill portions of the fundamental and supporting warfare tasks described in NWP-1 as necessary for the Navy's primary functions of sea control and power projection. Specifically, the AEW aircraft is involved in the fundamental tasks of Anti-Air Warfare (AAW), Anti-Submarine Warfare (ASW), Anti-Surface Ship Warfare (ASUW), and Strike Warfare plus the supporting tasks of Command, Control and Communications (C^3), and Electronic Warfare (EW).

2.1.2 THE ROLE OF THE AEW IN THE ANTI-AIR WARFARE TASK

The generic name of the AEW -- Airborne Early Warning -- implies its fundamental role in AAW. NWP-1 states that a carrier and its aircraft must have the capability, under all weather conditions, to detect and destroy enemy aircraft and cruise missiles. This capability is, in part, provided by the AEW platform and its avionics suite.

Anti-Air Warfare is multi-faceted due to the complexity of the threat and the variability of naval warfare scenarios. When a naval task force is involved in sea control operations, the AAW task becomes one of Early Warning and Fleet Air Defense. Threat forces likely to be encountered are bombers with anti-ship missiles, bombers with jamming equipment, fighters with air-to-air missiles and reconnaissance aircraft. The AEW responsibilities in this role include detection, classification, and identification of hostile air targets, dissemination of this information, and control of friendly fighters -- Combat Air Patrol (CAP) and Deck Launched Interceptors (DLI) -- and other local assets.

When power projection is the task force objective, the AAW task changes to tactical air control and target area protection. Surface-to-air missiles (SAMs) and ground-controlled interceptors (GCI) constitute the major threat. The AEW must now provide its standard Early Warning function, coordinate the Strike aircraft and control TARCAP (Target CAP) and/or BARCAP (Barrier CAP) fighters.

2.1.3 SCENARIO

It was essential, at this stage of the effort, to establish some limiting guidelines so that further work could be properly focused. The Fleet Air Defense role of the Anti-Air Warfare task was chosen for AEW algorithm development due to the criticality of task force defense and the complexity of the required decisions. The volume of information, the number and variety of combatants, and the sizable operator tasking suggest great potential benefits for the automation of these airborne C^2 decision processes. Accordingly, a major war-at-sea situation was postulated since a limited war environment is largely a subset of the former case. It was concluded that one AEW controlling two to four fighters was a realistic condition which was sufficient to encompass all basic airborne C^2 decision problems.

Using the above criteria, a representative scenario was prepared. It is an open-ocean war-at-sea scenario in which an AEW and several CAP stations are defending a task force from a high density, well coordinated threat. This scenario provides a reference for decision analysis and algorith development.

2.2 PROBLEM AREA IDENTIFICATION

AEW decision problems arise as the result of excessive information flow and its consequent data processing requirements. Most tactical decision failures are due to an inability to extract and integrate relevant data in an effective time-critical manner, rather than a failure to receive information. A function-level analysis was used to screen potential problem areas to identify major categories of AEW operator activity which satisfy two criteria: the functions identified should involve high data throughout and be defined as mission critical.

The reviewed documentation on the E-2C and V/STOL-A includes information on sequential mission phases and corresponding informational requirements. Using this data, functional units were defiend for which unambiguous input and output existed and from which tactical algorithms could be developed for each function, with the information products from one serving as input to the next. An Information Processing Flow Diagram for Airborne C^2 Decision Processes (Figure 2-1) shows the information flow and the relationships between the functional decision units that support the AEW mission.

To meet mission requirements, automated processing and integration of avionics data is required for the operator to obtain the best assessment of the aircraft tactical situation within a time-limited tactical environment. The mission problem areas suggested for automation are presented in Table 2-1.

An examination of Figure 2-1 shows that the functional units can be categorized into two groups. One group (Sensor Correlation, Threat Detection and Identification, and Target Track and Position Report) is based on the integration and evaluation of data to determine type of threat; the other (Threat Assessment, Engagement/Intercept Plan, and Force Coordination) is based on tactical planning to combat the threat. Although decision processes are involved in both, the first group is more finite and deterministic. Since rules and doctrine can be more precisely defined, these processes were the first ones addressed by previous automation efforts. Processes in the second group require generation and weighting of numerous complex tactical alternatives. The operator must combine diverse and not always well-defined data to select his next series of actions. Because of man's well-documented difficulties in optimally weighting and aggregating the right data to select decision alternatives, and because of the extremely critical nature of these decision processes for mission success, functions in the second group were identified as more appropriate for this task and recommended as potential areas of interest for further study (Table 2-1).

Four of the candidate problem areas, namely, Threat Assessment, Engagement/Intercept Planning, Intercept Control, and Force Coordination and C^2, are shown explicitly in Figure 2-1. The Threat Assessment function is responsible for determining threat maneuver capabilities, threat combat capabilities, and possible threat intentions. While the assessment of maneuver and combat capabilities is somewhat deterministic, assessing threat intentions is a more difficult decision process.

The Engagement/Intercept Plan is formulated from the results of the Threat Assessment Function and a knowledge of environmental status, own

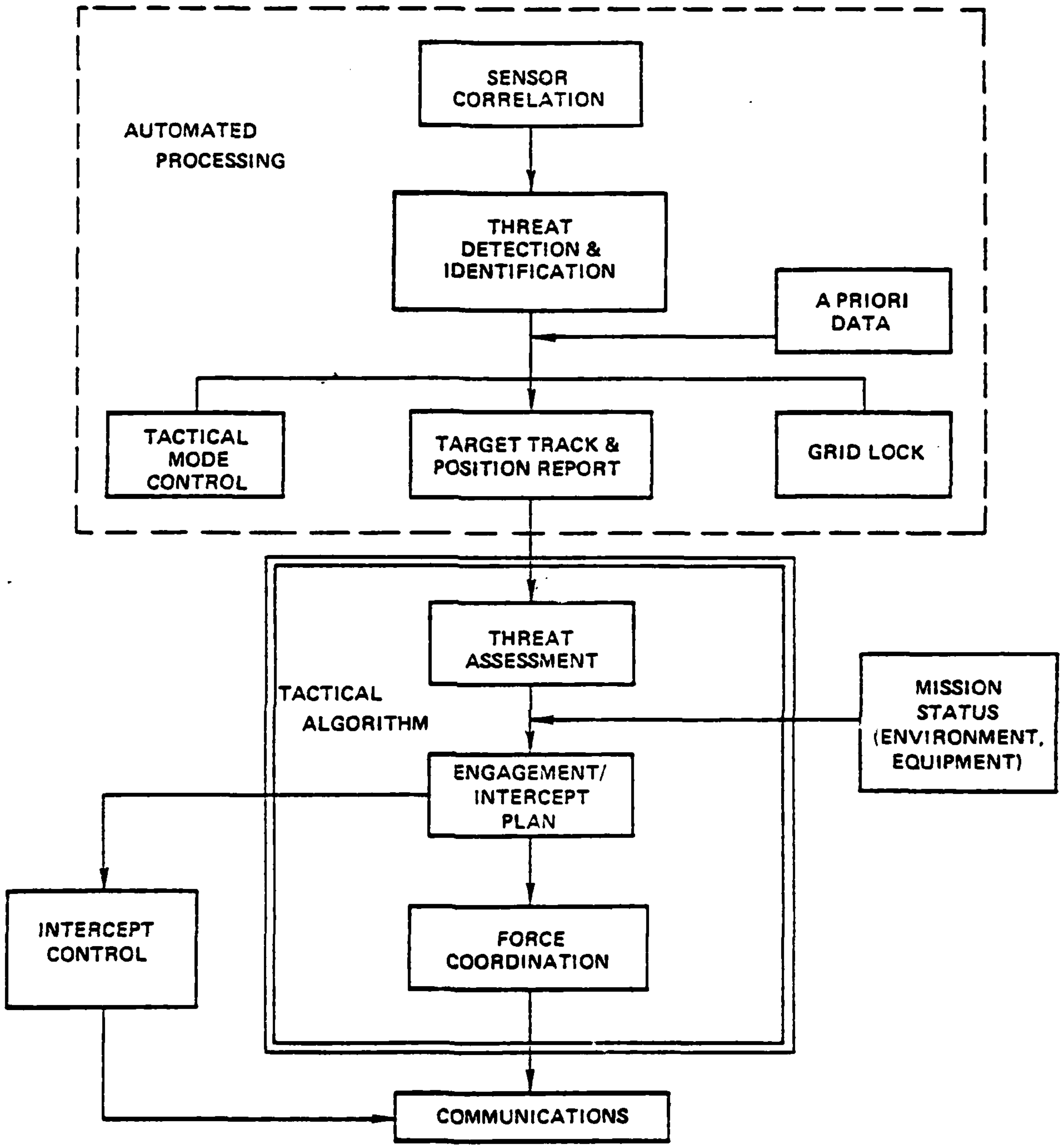


Figure 2-1. AEW Information Processing Flow Diagram for Airborne C^2 Decision Processes

TABLE 2-1

CANDIDATE AEW MISSION PROBLEM AREAS

- THREAT ASSESSMENT
- ENGAGEMENT/INTERCEPT PLANNING
- INTERCEPT CONTROL
- FORCE COORDINATION AND C^2
- COUNTERMEASURES AND SELF-DEFENSE
- AEW STATIONING (RESTATIONING)
- ATMOSPHERIC SURVEILLANCE PLANNING

force status, and own force capabilities. In addition to the primary task of assigning CAP fighters to their targets, the AEW may control such varied assets as deck-launched interceptors (DLI), tanker aircraft, ship-launched missiles, and the stationing of the AEW itself. How to optimally allocate all these resources is a decidedly complex decision problem.

The actual guidance of fighters to their targets is the purpose of Intercept Control. This control can be exercised either manually using verbal comments or automatically via data link and can be of an advisory or compulsory nature. As mentioned earlier, future high density threats will dictate greater reliance on automatic control in both uncoupled (advisory) and coupled (compulsory) modes. Manual control will be used only in exceptional or limited circumstances. Although intercept programs are currently implemented in the E-2C, they are not compatible with multiple attack fighters like the F-14 nor do they automatically adapt to a changing situation. The sophisticated Intercept Control function of the future should be tied to an automated Engagement/Intercept Planning function which can update itself as a situation unfolds.

The Force Coordination and C^2 function includes direction of those assets under AEW control other than fighters plus the necessary dissemination of information to other friendly forces. Like Intercept Control, this function must also be linked with an evolving Engagement/Intercept Planning function. The automatic dissemination of Force Coordination and C^2 information will help to offload the human decision maker in the AEW.

The remaining three candidate problem areas, Counter Measures and Self Defense, AEW Stationing (Restationing), and Atmospheric Surveillance Planning, are not shown explicitly in Figure 2-1. All three areas form a portion of one more of the depicted functions but are distinct enough to be considered separately.

AEW Counter Measures and Self Defense concern the AEW air frame's participation in engagement aside from its Command and Control task. Counter Measures and Self Defense includes the use of jamming, chaff, and flares plus the enforcement of emission control (EMCON). These measures will hopefully prevent enemy detection of friendly forces including the AEW, impede enemy targeting and neutralize enemy weapons. Planning the use of countermeasures is part of Engagement/Intercept Planning and their actual employment can be considered part of Force Coordination, but Countermeasures and Self Defense is a significant function in its own right.

An area related to the Engagement/Intercept Planning function and the concept of self defense is the AEW Stationing (Restationing) function.

Stationing for an AEW can be a complex decision based on such varied factors as:

- Relationship to friendly and threat forces
- Rules of engagement (ROE)

- Maintenance of required communication links
- Atmospheric conditions
- Geographic considerations
- Presence of other emitters

Initial Stationing decisions will be made prior to AEW take-off and thus the function is separate from the information flow depicted in Figure 2-1. However, for reasons of better mission execution and/or self defense, the Engagement/Intercept Planning function might want to restation the AEW. Thus, the Stationing function should be accessible to the Planning function.

Atmospheric Surveillance Planning is a function related to AEW Stationing, Engagement/Intercept Planning, and Countermeasures and Self Defense. It is based on current advances in atmospheric science. Recent studies have found that electromagnetic radiation is refracted by the atmosphere instead of always travelling in straight lines. The phenomenon is analogous to the propagation of acoustic waves in the ocean. These refractive properties cause the existence of "duct" layers in the atmosphere in which electromagnetic radiations travel much further than would normally be expected. In addition, the "ducts" act as barriers to emissions which try to penetrate them from above or below. The Airborne Microwave Refractometer (AMR), presently being installed on the E-2C, is a system which can perform atmospheric surveillance. Eventually, use of this information should be available to the AEW Stationing, Engagement/Intercept Planning, and Countermeasures and Self Defense functions mentioned above.

Selection of a single candidate problem area from the above group is described in Section 2.3.

2.3 PROBLEM AREA SELECTION FOR AUTOMATION ALGORITHM DEVELOPMENT

A consensual judment approach was used to evaluate the potential automation candidates on the following criteria: (a) the processes should be of sufficient clarity to allow for unambiguous automation; (b) data inputs and outputs should be thoroughly defined; and (c) the problem should be of manageable scope, but retain sufficient breadth to require complex decision logic. Using these criteria, the Engagement/Intercept Planning function was selected as the primary problem area for algorithm development/ demonstration. This area is the central tactical algorithm for the command and control function of the AEW mission, and as such, is critical to mission success. Man's ability to fulfill this function unaided in the complex post-1985 operational mission environment is considered questionable at this time.

3. APPLICATION OF THE DECISION METHODOLOGY TO THE AEW ENGAGEMENT?INTERCEPT PLANNING FUNCTION

3.1 THE METHODOLOGY

This section describes the decision methodology, its features, and an explanation of how these features are used in the present analysis.

3.1.1 FEATURES OF THE METHODOLOGY

The decision methodology includes three features necessary to analyze a decision problem area and bring the appropriate automated solution techniques to bear on it. The three features are a Model of the Decision Making Process, a Taxonomy of Decision Automation Techniques, and a pre-defined set of Categories for Decision Problem Description. These features and their interrelationships are described below.

3.1.1.1 MODEL OF THE DECISION MAKING PROCESS

An understanding of the decision making process is facilitated by the model used in the current effort. Decision making is neither invariant nor instantaneous, varying across both decision makers and decision problems. There are, however, a number of logical processes or processing functions which must be accessed every time a decision is made.

Six decision processing functions and their interrelationships form the general Model of the Decision Making Process depicted in Figure 3-1. The first of these is Problem Structuring, in which the problem is defined and the alternatives and contingencies are identified. The second is Prediction, in which the results of potential courses of action are estimated. The third function is Valuation, in which the possible courses of action and their potential outcomes are related to the decision maker's implicit or explicit preferences and goals. Data Handling, the fourth function, involves the manipulation, analysis, storage, and retrieval of objective and/or subjective information. The fifth function, Calculation, involves the numerical and logical manipulation of facts and relationships. Both Data Handling and Calculation are functions which support Prediction, Valuation, and the sixth and final function, Reasoning. Reasoning involves the drawing of inferences, use of heuristics, formation of judgments, and the general organization of the way in which the problem is approached.

The model of the Decision Making Process serves directly as a guideline for structuring a high level decision flow of the decision function being analyzed. The decision flow is basically a functional flow chart for the decision function showing the individual functional elements and the general order in which they are processed.

3.1.1.2 TAXONOMY OF DECISION AUTOMATION TECHNIQUES

The Taxonomy of Decision Automation Techniques (Table 3-1) is essentially a "shopping list" of proven techniques available for the automation of

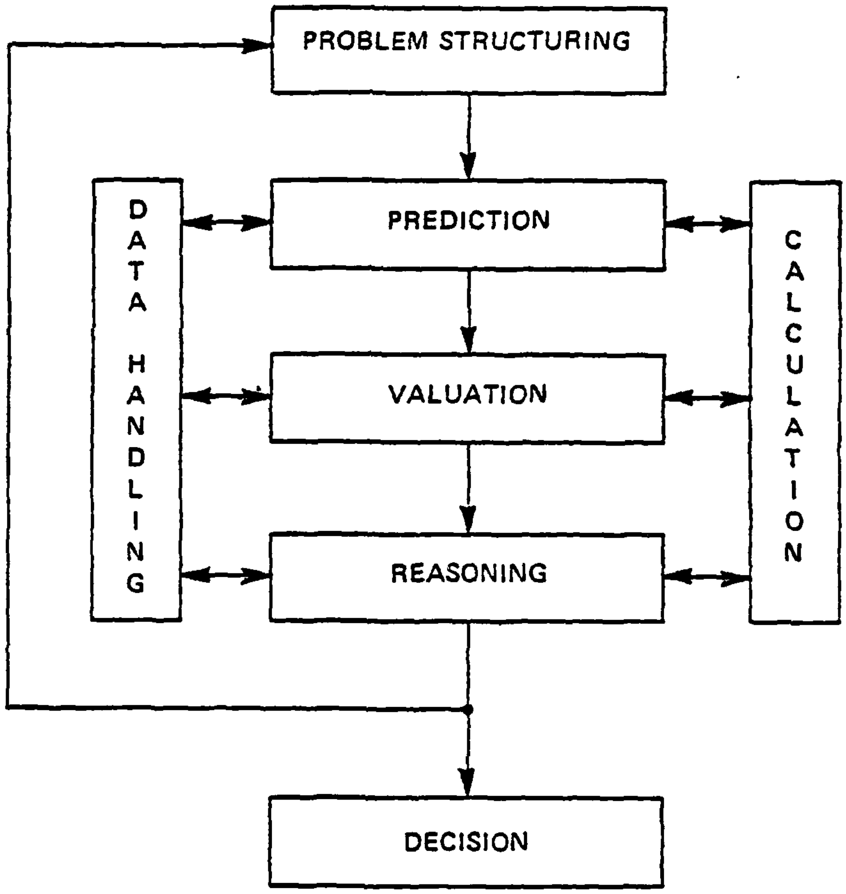


Figure 3-1. Model of the Decision Making Process

TABLE 3-1

TAXONOMY TO DECISION AUTOMATION TECHNIQUES

ANALYTIC	1.	PREDICTIVE TECHNIQUES
	1.1	Closed Form Analytic Models
	1.2	Probabilistic Models
	1.3	Deterministic Simulations
	1.3.1	Mechanical
	1.3.2	Differential Equation
	1.4	Monte-Carlo Simulations
	2.	VALUE MODELS
	2.1	Multi-Attribute Utility Model (MAUM)
	2.2	Adaptively Constructed MAUM
	2.3	Direct Assignment of Utilities to Outcomes
	2.4	Risk-Incorporating Utility Models
	2.5	Non-Linear Utility Model
	3.	DATA CONTROL TECHNIQUES
	3.1	Automatic Data Aggregation
	3.2	Data Management Techniques
	4.	ANALYSIS TECHNIQUES
	4.1	Optimization Techniques
	4.1.1	Linear Programming
	4.1.2	Non-Linear Programming
	4.1.3	Dynamic Programming
	4.1.4	Fibbonaci Search
	4.1.5	Response Surface Methodology
	4.2	Artificial Intelligence Techniques
	4.2.1	Heuristic Search
	4.2.2	Bayesian Pattern Recognition
	4.3	Sensitivity Analysis
	4.4	Intra-Process Analysis
	4.5	Information Processing Algorithms
	4.6	Status Monitor and Alert
	4.7	Statistical Analysis
	4.7.1	Distribution Comparison
	4.7.2	Regression-Correlation
	4.7.3	Discriminant Analysis
	4.7.4	Bayesian Updating
NON-ANALYTIC	5.	DISPLAY/CONTROL TECHNIQUES
	5.1	Display Graphics
	5.2	Interactive Graphics
	5.3	Windowing
	5.4	Speech Synthesis/Recognition
	5.5	Quickening
	6.	HUMAN JUDGMENT REFINEMENT/ AMPLIFICATION TECHNIQUES
	6.1	Operator-Aided Optimization
	6.2	Adaptive Predictions
	6.3	Bayesian Updating

decision functions. It was independently compiled after a review of existing decision aid and decision automation algorithms. (Each aid or automation algorithm usually incorporated not one but several techniques.)

The techniques thus identified were then cataloged into two broad groupings and subdivided into six categories.

One broad grouping is termed Analytic because of the four categories of techniques it encompasses are strictly computational in nature and have little or no direct interaction with a human decision maker. Predictive Techniques are mathematical models which calculate or predict the outcomes of real-world processes. Value Models are mappings from a description of preferences of decision makers onto a unidimensional scale of values. Those methods dealing with the representation and manipulation of data are labeled Date Control Techniques. Analysis Techniques include a wide variety of methods which assess data and predicted outcomes in light of the value structure to produce refined data and/or problem solutions.

The two technique categories which strongly involve the human decision maker within the decision automation algorithm are placed under the non-Analytic grouping. Display/Control Techniques serve as the man/machine interface enabling the human decision maker and the decision algorithm to convey information to each other. The Human Judgment Refinement/Amplification Techniques harness the human decision maker's innate capabilities for the decision making process.

The relationship between the techniques in the Taxonomy and the processing functions from the Model of the Decision Making Process is shown in Table 3-2. The value of the table to the development of a decision automation algorithm is that suitable techniques can be identified in rough fashion for the part of the decision process under consideration. The thrust of this methodology, though,, is to achieve a more rigorous matching through the use of the third feature of the Decision Methodology, Categories for Decision Problem Description.

3.1.1.3 CATEGORIES FOR DECISION PROBLEM DESCRIPTION

The description of a decision problem in terms of a predefined set of categories is an important vehicle for choosing appropriate automation techniques from the Taxonomy. These categories were selected to form both a comprehensive description of the problem and a natural bridge between the Model of the Decision Making Process, its corresponding high level decision flow, and the Taxonomy of Decision Automation Techniques. Each processing function from the Model of the Decision Making Process corresponds to one or more of the description categories.

The Problem Structuring function involves determining two basic descriptive features of the problem, the objective of the decision process, and the dynamics of the decision making task. While objectives will vary with every problem, there are three general dynamics that a problem may have:

TABLE 3-2

DECISION PROCESSING FUNCTIONS ADDRESSED BY THE DECISION AUTOMATION TECHNIQUES

		DECISION AUTOMATION TECHNIQUES \ DECISION PROCESSING FUNCTIONS	PROBLEM STRUCTURE	PREDICTION	VALUATION	DATA HANDLING	CALCULATION	REASONING
ANALYTIC	PREDICTIVE TECHNIQUES	CLOSED-FORM ANALYTIC MODEL		√		√	√	
		PROBABILISTIC MODEL		√		√	√	
		DETERMINISTIC SIMULATION		√		√	√	
		MONTE-CARLO SIMULATION MODEL		√		√	√	
	VALUE MODELS	MULTI-ATTRIBUTE UTILITY MODE (MAUM)			√		√	
		ADAPTIVELY CONTRUCTED MAUM			√			
		DIRECT ASSIGNMENT			√			
		RISK INCORPORATING			√		√	
		NON-LINEAR			√		√	
	DATA CONTROL TECHNIQUES	AUTOMATIC DATA AGGREGATION		√	√			
		INFORMATION MANAGEMENT		√	√			
	ANALYSIS TECHNIQUES	OPTIMIZATION TECHNIQUES		√	√			
		ARTIFICIAL INTELLIGENCE TECHNIQUES	√	√				
		SENSITIVITY ANALYSIS				√	√	√
		INTRA-PROCESS ANALYSIS		√	√		√	
		INFORMATION PROCESSING ALGORITHMS	√	√	√	√	√	
		STATUS MONITOR AND ALERT				√	√	
		STATISTICAL ANALYSIS		√	√	√	√	√
NON-ANALYTIC	DISPLAY/CONTROL TECHNIQUES	DISPLAY GRAPHICS	√			√	√	
		INTERACTIVE GRAPHICS	√			√		
		WINDOWING				√		
		SPEECH RECOGNITION/SYNTHESIS				√		
		QUICKENING		√			√	
	HUMAN JUDGMENT REFINEMENT/AMPLIFICATION TECHNIQUES	OPERATOR-AIDED OPTIMIZATION					√	√
		ADAPTIVE PREDICTION		√	√	√	√	√
		BAYESIAN UPDATING		√		√	√	

- Closed-Loop Iterative -- Problems in which a single decision msut be made repetitively in a short time frame, for example, in discrete tracking or monitoring processes/tasks.

- Sequential Contingent -- Problems in which a number of different decisions must be made, one each, and in sequence.

- Uni- or Multi-Dimensional Independent -- Problems in which one or several decisions must be made only once and without consideration to subsequent decisions.

Thus, the first two problem description categories are the identification of the Objective of the problem and the Task Dynamics of the decision situation.

The Prediction function addresses the basic process(es) that underlie the problem, since it is the outcomes of the process that must be predicted. The Valuation function involves the application of specific value criteria to prioritize the predicted outcomes. Thus, the third and fourth categories of the problem description will be the identification of the Underlying Process and Value Criteria used to evaluate related predicted outcomes.

The Data Handling function addresses the manipulation of the various input variables, output variables, and parameters that make up the decision problem, so the fifth problem description category is the identification of the Variables and Parameters which comprise the data for the decision. The Calculation function, in addition to direct support of the Prediction and Valuation functions, involves the various analyses that must be performed on the Variables and Parameters to arrive at an optimal solution to the problem. Thus, the sixth problem description category is the identification of the Relevant Analyses for the decision problem.

Finally, the Reasoning function relates to the way the human decision maker monitors, oversees, and overrides the decisions of the automated algorithm. There are judgments and inferences that the man must make in monitoring the problem, and displayed information to which he must have immediate access in order to perform this function. Therefore, the seventh and eighth problem description categories are the identification of the Required Human Judgments and the Relevant Displays.

The problem description categories which can be applied to a given decision problem are summarized as follows:

- Objective -- What is the goal of the decision making process? Is there some event or events that must be achieved in order to successfully solve the decision problem?

- Task Dynamics -- Which of the three kinds of dynamics apply to this problem?

- Underlying Process -- What is the real-world process, if any, which is associated with this decision problem? What are the interactions with the enemy, or other outside parties?

- Value Criteria -- On what kind of scale could a decision be evaluated? Are there one or more measures by which one choice can be viewed as better than another?

- Variables and Parameters -- What are the inputs to the decision? What are the (fixed) parameters of the decision making situation which may affect the decision? What is the specific decision(s) that must be made? What are the outputs from each decision?

- Relevant Analyses -- What kinds of analysis of the input/output parameter data would help in making the decision?

- Required Human Judgments -- What aspects of the decision process must rely on human judgment? On inferences and heuristics? What are the basis for the judgments and inferences? What heuristics might be involved?

- Relevant Displays -- What information should be displayed to allow the required human judgments, etc., to be made? How should it be formatted?

The close correspondence between the problem description categories and Taxonomy categories can now be demonstrated. Predictive Techniques model and predict results of real-world Underlying Processes associated with decision functions. Value Models quantify and represent the Value Criteria. Data Control Techniques are used to manipulate and construct the Variables and Parameters relevant to the decision functions. Analysis Techniques are used to provide the Relevant Analyses, and Display/Control Techniques are used to provide the Relevant Displays. Human Judgment Refinement/Amplification Techniques enhance the intuitive problem solving abilities of the human decision maker called for by the Required Human Judgments. The Objective and Task Dynamics do not have corresponding Taxonomy Categories because the Objective is a succinct statement of purpose and the Task Dynamics refer to the repetitiveness of the decision function.

3.1.2 USING THE METHODOLOGY

The purpose of the methodology is to identify and organize those techniques appropriate for automating a given decision function. The three steps required to achieve this purpose are directly related to the three features of the methodology discussed above. While the steps constitute a straightforward procedure, it is not uncommon that several iterations may be needed to attain acceptable results.

The steps for using the methodology are as follows:

- Step 1 - Chart the High Level Decision Flow for the Decision Function

  Using the Model of the Decision Making Process as a guide, the decision function should be broken down into its individual functional elements. The decision flow which exists among these functional elements can then be charted.

- Step 2 - Describe the Decision Function According to the Categories for Decision Problem Description

  By answering the questions posed in Section 3.1.2.3 for each problem description category, a comprehensive description of the decision function can be generated.

- Step 3 - Match the Appropriate Techniques from the Taxonomy of Decision Automation Techniques to the Decision Function Description

  Techniques that are appropriate to a decision automation algorithm are determined by reviewing each category of the decision function description against the corresponding category in the technique taxonomy, and choosing those techniques that are applicable to that part of the problem. Thus, the matching may or may not result in the choice of a single technique from each category. When it does not, the known constraints of the situation can be applied against the characteristics of the techniques chosen, to eliminate less appropriate alternatives. If more than one technique in a category still remains, then these techniques represent legitimate alternative approaches to the automation of the decision process.

At the satisfactory conclusion of Step 3, a list of applicable techniques and a decision flow framework for organizing them will have been produced.

The remainder of Section 3 describes the application of the methodology to the AEW Engagement/Intercept Planning function. Sections 3.2, 3.3, and 3.4 discuss Steps 1, 2, and 3 respectively.

3.2 HIGH LEVEL DECISION FLOW FOR THE ENGAGEMENT/INTERCEPT PLANNING FUNCTION

The High Level Decision Flow for the Engagement/Intercept Planning function is presented in Figure 3-2. It was prepared using the Model of the Decision Making Process as a framework for identifying and organizing the functional elements which comprise the decision function.

The associated processing functions from the Decision Making Process Model are indicated in the right-hand column of Figure 3-2 to show its influence on the decision flow. The list of processing functions depicted reflects the

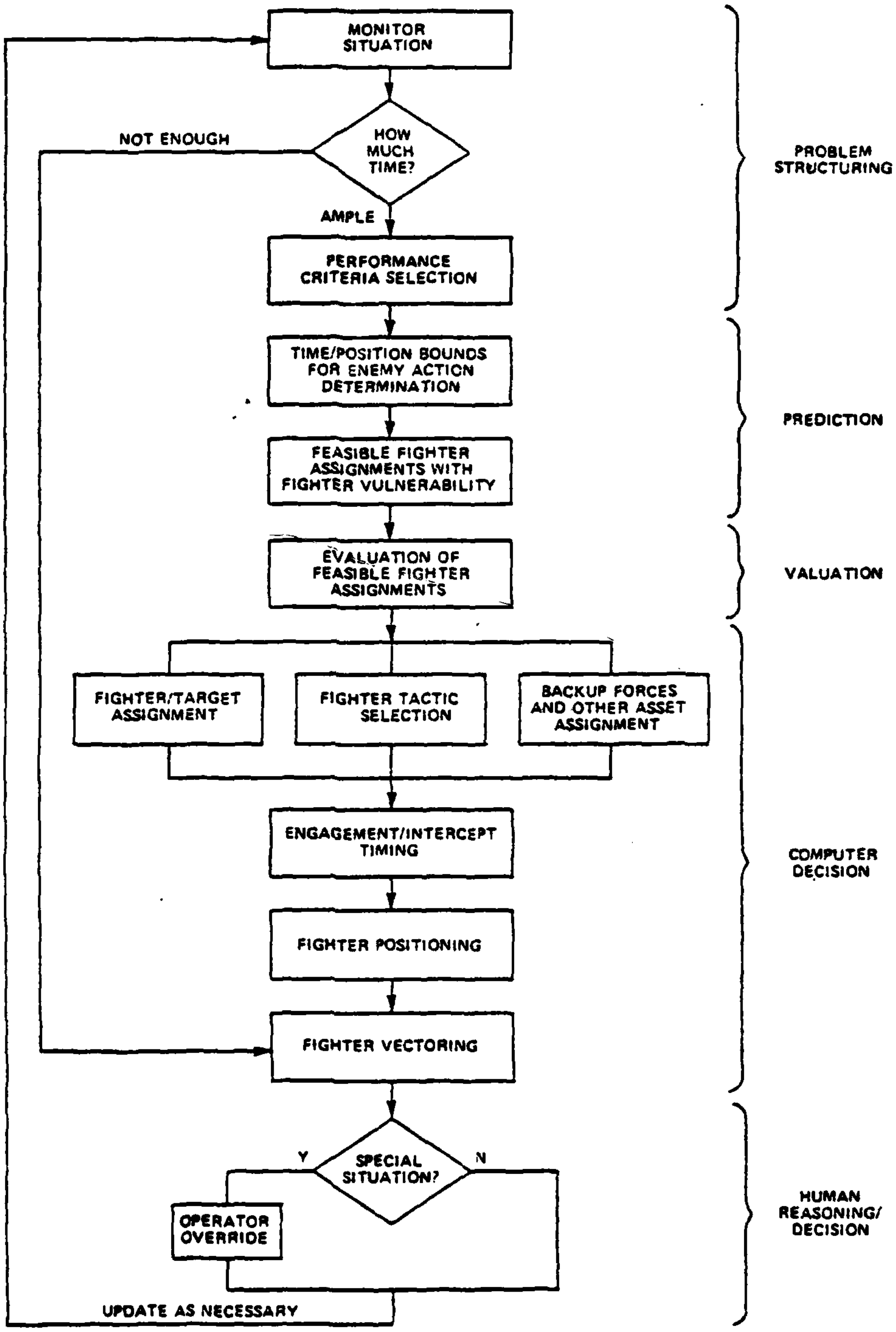


Figure 3-2. High Level Decision Flow for the Engagement/ Intercept Planning Function

modification required when the abstract model was adapted to the concrete decision automation problem. The Problem Structuring, Prediction, and Valuation functions appear in similar fashion but the Calculation and Data Handling functions do not appear explicitly because they play a supporting role in the other functions. How to apportion the Reasoning function between man and machine is both a theoretical and practical issue. For purposes of this study, it was decided that the term Reasoning would be used to describe processes carried out by the human decision maker exclusively. Therefore, the diagram shows the computer making a decision after performing the Valuation function. This Computer Decision is reviewed by the human decision maker who can exercise his Reasoning capability to decide whether to accept the computer decision.

The functional elements which correspond to each of the processing functions from the Model of the Decision Making Process are enclosed by the brackets in the figure. It should be noted that these assignments are somewhat arbitrary because overlap exists in several instances. For example, determining how much time is available for planning require prediction of enemy action and selection of performance criteria can be considered part of the Valuation function.

The Problem Structuring function includes monitoring the situation, determining how much time is available for planning, and selecting the performance criteria for evaluating the plan. Monitoring of the situation is the continuous process of receiving real-time input data on the opposing forces and on the environment. Of special interest for the Engagement/Intercept Planning function are monitoring of friendly force systems status and the recognition of multiple attack possibilities for the fighters under AEW control. Answering the question of how much time is available for planning is crucial in an operational environment. If enemy attack is imminent, the AEW planning problem is reduced to immediate vectoring of the nearest fighter or fighters. When more time is available, time limits for planning and friendly force reaction are need to structure the problem. Different performance criteria may be selected depending on the task force objectives and the nature and size of the threat.

The Prediction processing function is involved with determination of time and position bounds for enemy action and the identification of feasible fighter/target assignments to counter those actions. The evaluation of the feasible fighter assignments fulfills the Valuation processing function. Based on the previous evaluation, the computer can then decide on fighter/target assignments and tactics, plus backup forces and other asset assignments. Once the assignments are finished, the timing for employing these forces in the ensuing engagement can be coordinated. Determination of this timing leads directly to the positioning and/or vectoring of the friendly fighters.

The completed computer plan must then be reviewed by the human decision maker. The human must be alert for special situations such as friendly systems status failures or opportunities to use innovative tactics. In these cases, he must exercise his operator override capability.* The planning function will then

*Although the operator override functional element is shown at the end of planning function, it is probable that the operator may need to intervene at other points in the planning process.

be updated or repeated as necessitated by operator direction or a changing situation.

3.3 DETAILED DESCRIPTION OF ENGAGEMENT/INTERCEPT PLANNING FUNCTION

The Engagement/Intercept Planning function begins at the time the AEW platform has classified and possibly identified one or more enemy aircraft, and has assessed them to be threats to the task force. The function therefore begins when Detection, Identification, and Assessment of threat have been accomplished (see Figure 2-1). The Engagement/Intercept Planning function ends and the Intercept Control function begins when the friendly fighter is in intercept range of the threat aircraft. It should be understood, however, that these beginnings and endings are as much logical boundaries as they are temporal demarcations. Threat Detection, Identification and Assesment continue to be concerns during the planning of the engagement, and all three of these continue to some degree during execution of the Intercept Control decision function. The boundaries established above between all these situations primarily serve to indicate the domains of decision making within each of these decision situations.

3.3.1 OBJECTIVES

During the Engagement/Intercept Planning function, the AEW attempts to devise a battle plan for the ensuing interception of hostile targets by fighters under AEW control. The objective of this function is to optimally allocate the resources under the AEW's control, to maximize the damage inflicted on the enemy force, and/or to minimize the damage to the friendly task force. This allocation will come in the form of a sequential engagement/intercept plan for each asset under AEW control.

3.3.2 UNDERLYING PROCESS

In this situation, the one or more identified hostile targets are heading in the general direction of the task force, while the AEW and CAP are flying their assigned on-station courses. The process involved in this situation, therefore, is the movement of the hostile targets toward the task force, the orbiting of the AEW platform and the movement of available friendly fighter to intercept them. The hostile targets may be taking evasive action or employing Electronic Countermeasures (ECMs) to avoid engagement by the friendly interceptors.

3.3.3 VALUE CRITERIA

Any decision function, AEW Engagement/Intercept Planning included, encompasses a number of subsidiary decision functional elements. Each of these will necessarily have its own value criteria. Often, these criteria will be well-defined by the physical parameters involved in the task. The decision of how much time is available to engage the enemy force, for example, will be made subject to the obvious criterion of neutralizing the incoming force before it is able to attack the friendly task force. However, the problem faced in the overall decision situation is to trade-off the individual decisions in such a way as to fulfill the mission objective. Therefore, the situational value criteria should relate not to the detailed considerations of the individual decision elements, but to the more global considerations of the entire mission.

Two possible criteria by which a potential engagement/intercept plan could be evaluated are a measure of the expected reduction of the number of hits on the friendly task force, and a measure of increase in the ratio of the expected number of threats intercepted to the expected number of friendly aircraft destroyed.

3.3.4 VARIABLES AND PARAMETERS

The decision automation algorithm will require two kinds of information to use in its computations, input variables and parameter variables. The difference between the inputs and parameters to the situation lies in the volatility of the information they represent. Input variables represent data that may change during the course of a single AEW mission, and will always change from mission to mission. Input data is gained during the mission through dynamic sources, in particular from sensors, data links, and other decision processing functions. Parameter information, on the other hand, will remain constant within a given mission, and possibly over longer periods of time. It represents information that can be stored in on-board static data files prior to the mission and retrieved as needed. The parameter data can, therefore, be viewed as information which comprises the on-board a priori data base for the decision automation algorithm.

In addition to the input variables there are other variables for which the automation algorithm will be estimating a value. These are the decision variables for the decision function. The value assigned to each decision variable may result in values being assigned to another set of variables, the output variables for the decision function.

3.3.4.1 INPUT VARIABLES

There are several sets of input variables to the Engagement/Intercept Planning function:

- There is information on the incoming hostile force. This includes the sensor-based track information on the hostile targets, any classifications of hostile targets that have been made, and assessment of the fuel and weapons system status of the hostile aircraft.

- There is the sensor-based track information on all other targets in the area, whether friendly, neutral or unidentified.

- There is the prioritization of these hostile targets according to the threat they pose to the task force.
- There are the variables which deal with the electronic warfare (EW) environment -- the nature of the EW environment, and the electromagnetic propagation conditions present.
- There are variables which identify the status of the friendly forces. For the airborne forces, this includes the status of their fuel supply, weapons systems, and non-weapons systems (e.g., radar, communication, navigation), as well as an indication as to which fighters are assigned to each combat air patrol (CAP) station. For the ship-based resources, including deck-launched interceptors (DLI), the variables include the time required for them to be brought into the engagement, and the number of units available.
- There is information on the atmospheric conditions in the area of operations.
- There is information on the tactical environment of the engagement.

3.3.4.2 PARAMETERS

There are basically two sets of parameters for this problem, one concerning enemy capabilities, and one concerning friendly capabilities. The parameters which relate to the enemy can be termed "intelligence parameters," and are of two types: those which deal with weapons and/or platform capabilities, and those which deal with operations and procedures. Specific parameters of the first type include the range and capability of each weapon available to the enemy, the types of platforms from which each weapon can be fired, and the maneuvering and EW capabilities of each type of enemy platform. Specific intelligence parameters of the operations and procedures type include the inventory of tactics the enemy may use, his projected rules of engagement (ROE), the C^3 structure of the enemy force, and the return-to-base considerations for incoming enemy aircraft.

A similar set of parameters apply to the friendly force capabilities, specifically: the maneuvering and weapons capabilities of friendly platforms, the capabilities and firing ranges of friendly forces, and the currently employed ROEs. Included in the maneuvering capabilities of the friendly fighters are the limitations imposed by the presence of the crew, such as G-force limitations and turning radius limitations.

3.3.4.3 DECISION VARIABLES

There are eight decision variables involved in the Engagement/Intercept Planning function. The first two are the determination of the threat time to the task force "bubble of vulnerability" (BUVUL) and the related time available to construct and implement an engagement/intercept plan. The third is the selection of a performance criterion for the plan, which involves choosing a criterion by which the goodness of the engagement/intercept will be judged against the global value criteria for the situation. An example of a performance criteria would be maximizing the average number of hostile aircraft intercepted before they are within weapons range of the friendly task force.

The fourth decision variable is the assignment of hostile targets to friendly fighters. The fifth is the selection of a tactic for each intercept. The third and fourth decision variables are obviously related, as each is considered in deciding a value for the other. The sixth variable is the determination of a time to engage each hostile aircraft.

The seventh variable is the determination of an initial position for a given intercept, at which point, autonomous control will be turned over to the intercepting fighter. The eighth is a set of vectors by which a given intercept will be controlled by the AEW aircraft.

3.3.4.4 OUTPUT VARIABLES

The eight decision variables correspond closely to the output values for the Engagement/Intercept Planning function. The outputs are the calculated time available for action, a criterion for evaluating an engagement/intercept plan, a pairing of friendly fighters with hostile targets with priorities for each target, a tactic for the intercept of each target, a specific time to engage each target, initial positions or intercept vectors for each friendly fighter, and any requests for backup forces, such as DLI or tankers.

3.3.4.5 RELEVANT ANALYSES

There are four type of analyses using the input variables and parameters necessary for the Engagement/Intercept Planning function. The first is recognition of threat "cells" (enemy formations that can be handled with a multiple-attack fighter). The second is analysis of enemy tracks and platform capabilities to create boundaries for the location of each enemy aircraft over time. The third is maximization of friendly fighter utilization subject to the constraints of possible enemy movement, multiple-engagement capability, threat prioritization, and time available to act. The fourth is monitoring the status of friendly aircraft to identify failures in any of their systems which could mandate changes in the engagement plan.

3.3.4.6 RELEVANT DISPLAYS

A decision automation algorithm will need to display information to the human operator for two purposes: telling the operator what action has been taken, and allowing the human decision maker to understand the action and its justification as it is unfolding, so that he can intercede and override the automated decisions.

There are six displays formats which are possibly relevant for these purposes. First, a display of the tactical operations area containing track data, a depiction of the "bubble of vulnerability" of the task force to each type of enemy weapon (see Section 4.2.2), the pairing of the friendly fighters with enemy targets, and the tactics chosen for each intercept. The second is a display which shows any single friendly fighter and its currently assigned targets, along with all relevant information regarding the motion, status, and capabilities of both. The third display would simply be a listing of the currently employed rules of engagement. The fourth would be a listing of the current status of each major system on each friendly aircraft. The fifth would be a display of all requests made for backup forces, and the sixth would be a display of the time available to intercept each hostile target. Many of these displays can be integrated onto a composite display format.

3.3.4.7 REQUIRED HUMAN JUDGMENTS

In a decision automation context, a required human jdugment is the identification of anomolous conditions that can confound the automated decision algorithm and cause it to perform incorrectly. When such conditions exist, the human decision maker must override the algorithm decision and take appropriate action. The precise definition of the required human judgments, therefore, depends on what constitutes a set of "unforeseen circumstances". Since all circumstances that can be anticipated will be built into the automation algorithm, it is difficult to precisely define those conditions for which the human decision maker should be alerted.

Another context for human judgment is in the area of special tactics. An experienced human decision maker may be able to devise novel tactical solutions for specific mission scenarios when freed of the burden of normal Engagement/Intercept Planning functions by the automated decision algorithm.

3.3.4.8 TASK DYNAMICS

The task dynamics of this situation are sequential contingent, as the AEW decision maker must first plan the allocation of his resources, then position them so as to make the chosen allocation feasible, assign targets to the individual fighters, and choose and relay intercept tactics, while coordinating the movement of airborne tankers, the launching of DLI, and the utilization of other shipboard/airborne assets. The sequential contingent nature of the situation is evident from the high level flow pictured earlier in Figure 3-2.

3.3.4.9 SUMMARY

The description of the Engagement/Intercept Planning function is summarized in Table 3-3.

3.4 MATCHING TECHNIQUES TO THE NEEDS OF ENGAGEMENT/INTERCEPT PLANNING

Each technique category is reviewed in relation to its corresponding problem description category to identify those techniques applicable for the Engagement/Intercept Planning function. The results of the matching process are summarized in Figure 3-3.

TABLE 3-3

ENGAGEMENT/INTERCEPT PLANNING DESCRIPTION

OBJECTIVE: Prepare an engagement/intercept plan for all assets under AEW control.

UNDERLYING PROCESS: Movement of one or more enemy aircraft toward friendly task force and movement of one or more friendly fighters to intercept and engage them.

VALUE CRITERIA:
1. Measure of expected reduction in number of hits on friendly task force.
2. Measure of increase in $X = \dfrac{\text{expected number of threats intercepted}}{\text{expected number of friendly aircraft destroyed}}$

VARIABLES AND PARAMETERS:

INPUT VARIABLES

Track information for all forces.
Hostile track identifications and classifications.
Threat prioritization of enemy targets.
Estimated enemy weapon and fuel status.
EW environment.
Electromagnetic propagation conditions.
Tactical environment.
Available friendly-force backup.
Atmosphere conditions.
Friendly platform status:
- Weapon systems
- Fuel supply
- Non-weapon systems

DECISION VARIABLES

Threat time to Task Force BUVUL
Time available to plan
Performance criterion selection
Assignment of targets to fighters
Tactic selection
When to engage
Positioning
Vectoring

PARAMETERS

Intelligence on enemy capabilities:
- Weapons types, ranges, capabilities
- Platform types, capabilities
- Platform-weapon combinations
- EW capabilities

Intelligence on enemy operations:
- Return-to-base considerations
- C^3 structure
- Projected ROE

Friendly platform capabilities:
- Weapons
- Maneuvering
- EW
- Man limitations

Own-force tactics available.
Current ROE.

OUTPUT VARIABLES

Time available for planning and intercept
Criteria for target allocation
Target allocation with priorities
Intercept tactics for each target
Initial position or vectors for each intercept
Requests for backup forces, especially DLI

RELEVANT ANALYSES:
1. Recognition of threat 'cells' that can be handled by a multiple-attack fighter.
2. Establishment of time and position bounds for enemy action.
3. Maximization of fighter and other asset utilization consistent with time available and threat priority.
4. Monitoring of friendly-force status for system failures causing change of plan of action.

RELEVANT DISPLAYS:
1. Depiction of "bubble of vulnerability" for task force to each enemy weapon and assignments of targets to fighters with chosen tactics.
2. Detailed display of single fighter-current target, with all additional information available.
3. Listing of rules of engagement.
4. Listing of status of all systems on all friendly fighters.
5. Listing of requests for backup forces.
6. Time available to intercept each hostile target.

REQUIRED HUMAN JUDGMENTS:
1. Identification of anomolous conditions which will require the human operator to override the algorithm's decision.
2. Use of special tactics.

TASK DYNAMICS: Sequential contingent.

TECHNIQUES

PREDICTIVE

- √ CLOSED-FORM ANALYTIC
- √ PROBABILISTIC
- DETERMINISTIC
- MONTE CARLO

VALUE MODELS

- √ MULTI-ATTRIBUTE UTILITY
- ADAPTIVE MAUM
- RISK INCORPORATING
- DIRECT ASSIGNMENT
- √ NON-LINEAR

+ DATA CONTROL

- AUTOMATIC AGGREGATION
- INFORMATION MANAGEMENT

ANALYSIS

- √ AUTOMATIC OPTIMIZATION
- √ ARTIFICIAL INTELLIGENCE
- SENSITIVITY
- INFORMATION PROCESSING
- INTRA-PROCESS
- √ STATUS & ALERTING
- STATISTICAL

DISPLAY/CONTROL

- √ DISPLAY GRAPHICS
- √ INTERACTIVE GRAPHICS
- √ WINDOWING
- √ SPEECH SYNTHESIS/RECOGNITION
- QUICKENING

★ HUMAN JUDGMENT REFINEMENT/AMPLIFICATION

- OPERATOR-AIDED
- ADAPTIVE PREDICTION
- BAYESIAN UPDATING

LEGEND

√ APPROPRIATE TECHNIQUE

★ TECHNIQUE OF THIS CATEGORY NEEDED, BUT NO EXISTING TECHNIQUE APPROPRIATE

+ TECHNIQUES FROM THIS CATEGORY NEEDED, BUT SHOULD BE SEPARATE FROM ALGORITHM

Figure 3-3. Decision Automation Techniques Applicable to the Engagement/Intercept Planning Function

3.4.1 PREDICTIVE TECHNIQUES

The underlying process for the Engagement/Intercept Planning function concerns the motion of aircraft over time. Because this type of process has been well studied and is well understood, an analytic model is possible. There are two types of analytically-based predictive techniques: probabilistic models and deterministic closed-form models. The deterministic model requires less computational time and space than the probabilistic model while the probabilistic model allows for the uncertainty inherent in predicting future locations of enemy aircraft. The greater computational complexity of the probabilistic approach may be somewhat mitigated by technological hardware improvements in the time frame of interest bu the deterministic form will still be faster and simpler if the same technology is applied to it. The primary purpose of the predictive technique will be to provide models of aircraft motion to the decision algorithm's analysis components. This means that the probabilistic considerations could just as easily be incorporated in the analysis technique that interfaces with the predictive technique, as in the predictive technique itself.

No clear basis (other than that of computational speed) exists for choosing one of these two forms of predictive techniques over the other, so both of them will be considered as applicable to the decision algorithm.

3.4.2 VALUE MODELS

All but two of the value models listed in Table 3-1 require some kind of preference structure to be provided by a human decision maker each time a decision is made, in order for the general form of the model to be related to the specific choices at hand. While this kind of intensive interaction between the human and the computer is acceptable in a decision aid, it is unacceptable in a decision automation algorithm. Therefore, only those value models which do not have this interaction characteristic, namely, the multi-attribute utility model (MAUM) and the non-linear utility model (NUM), can be considered for the decision algorithm.

Both of these models allow the use of fixed formulae to valuate alternatives in different instances of the same decision by considering not the alternatives involved but the underlying attributes of the alternatives. The primary difference between the MAUM and the NUM is that the MAUM assumes that all the attributes involved are independent and their effects additive, while the NUM does not. The MAUM can, therefore, be thought of as a special case of the NUM.

It is unlikely that the restrictive assumptions of a MAUM can be met in a decision algorithm for the Engagement/Intercept Planning function, as many of the attributes of the decision variables are likely to be related. For a pairing of friendly fighters to hostile targets, for example, such attributes as the speed of engagement, the P_k (probability of kill), and the weapons used are likely to be highly dependent on one another. A NUM is, therefore, the most appropriate type of value model for the situation.

On the other hand, non-linear functions (such as those used in a NUM), may have singularities that are not apparent from a cursory assessment, while additive linear functions (such as those used in MAUM) do not. The use of non-linear utility models will require a thorough numerical analysis of the utility function to ensure that there are no conditions under which the model may produce meaningless or physically impossible results.

3.4.3 DATA CONTROL TECHNIQUES

The unique role of the AEW platform in both collecting and disseminating large amounts of information is reflected in the numerous inputs, outputs, and parameter variables relevant to the Engagement/Intercept Planning function. It is necessary for the Engagement/Intercept Planning algorithm to interface with a data management system, but the same can also be said for all of the other potential AEW decision algorithms. Since this data base must interface with all of the decision algorithms, it should not be a specific part of any one of them. Information management techniques are, therefore, not appropriate to this decision automation function. A similar argument applies to data aggregation. Because of the enormous volume of incoming raw data and processed information, it will be necessary for each automation algorithm to have access to aggregated and disaggregated data as needed. But because this aggregation/disaggregation will have to be available to all potential decision algorithms, it should be incorporated into none of them. Instead, both the data aggregation and the data management systems should be separate, stand-alone subsystems of the overall AEW avionics.

3.4.4 ANALYSIS TECHNIQUES

The techniques that will analyze the Underlying Process in light of the Input and Parameter data, in order to maximize the value criteria, will constitute the heart of the decision automation algorithm. Four separate analyses were identified as relevant to this situation and each will be discussed separately.

The recognition of "cells" of threat aircraft which can be attacked simultaneously by a multiple-attack fighter is an important task. The standard pattern recognition techniques of artificial intelligence are suitable for solving this problem. The only difficult portion of this analysis lies in determining which aircraft flight characteristics are necessary to define a "cell".

The establishment of time and position bounds for the enemy is essentially an information-processing task and can therefore be accomplished with some sort of information-processing algorithm. The boundaries to aircraft motion are determined by the current location of the platform and its maneuvering capabilities. Deterministic procedures could thus be used to identify the future possible locations. However, the motion of the enemy aircraft will also be constrained by their own goals of attacking the task force, so an artificial intelligence (AI) approach could be employed to further restrict the future locations of the aircraft to those which are consistent with a potential attack on the task force. In particular, a simple AI look-ahead inference algorithm could be constructed which would, for each movement of an enemy aircraft, infer from the enemy's ROE, the task force location, and the future movement capability of the enemy aircraft, whether that movement could ultimately lead to an attack on the task force.

The maximization of fighter and other asset utilization subject to the constraints stated in the situation description can be accomplished through a standard optimization technique, particularly some form of mathematical programming. The use of these techniques would guarantee an optimal solution if enough time were available to compute it. This is not a trivial constraint. Conventional linear and non-linear programming methods are susceptible to degeneracy problems in which the computation of a solution becomes infeasible. It would be disastrous if the algorithm encountered one of these problems and was therefore unable to allocate the friendly fighter resources. New developments in mathematical programming (see References 7 and 8) hold open the possibility of new algorithms which do not have this shortcoming. Second, some forms of mathematical programming, especially dynamic programming, do not hill-climb (i.e., take sub-optimal solutions and iteratively improve on them) but instead produce no solution (not even a sub-optimal one) until all the computations are finished. Thus, if the time available is even a few microseconds short of what the algorithm needs to finish, there will be no solution when the "must act" time threshold is reached. An alternative to formal optimization is an artificial intelligence "problem-solving" technique, such as heuristic search. In this approach, the range of all possible utilization is represented as a "search space". The algorithm will systematically search for an optimal utilization with the aid of a "heuristic" or intelligent rule. This rule will tell the algorithm where in the search space it should suspect a better solution is located, given the knowledge of the search space that the algorithm has obtained by searching parts of it. The advantage of this approach is that it produces "good" but sub-optimal solutions very quickly. In fact, such an algorithm will normally produce a solution of given degree of goodness much faster than a hill-climbing algorithm. The drawback is that there is no upper limit to the number of computations it may need to find the globally optimal solution. At present, there is no basis for selecting either the optimization or the AI approach, particularly until the newer techniques in linear programming have had a chance to develop further.

Finally, the monitoring of friendly-force status for systems failures which could affect the overall plan could be accomplished by an alerting system in which the specific conditions to be searched for are established by the algorithm itself.

3.4.5 DISPLAY/CONTROL TECHNIQUES

Six different types of displays were listed in the situation description as being relevant. The first of these is the tactical display of track data, the various vulnerability bubbles, the location of each of the enemy and friendly aircraft, and the assignments of enemy aircraft to friendly fighters. Since this display is essentially a display of overall geometry, it can only be constructed with graphic display techniques. The second listed display would show the relative geometry of any particular fighter-target pairing, along with all additional information available for the platforms involved. This display also will require graphic display techniques.

The remaining four displays of the ROE, the status of all friendly aircraft, the time available for intercepts, and the requests for backup forces, can be accomplished with standard alphanumeric display techniques. In the AEW aircraft of the future, there will likely be a premium on display space. This suggests that a single display device be used for these four alphanumeric displays, with the appearance of a given display controlled by a switch-selection or menu-selection process. The human operator in his overseeing role will require constant access to all displays.

The exercise of operator control is heavily dependent on the Human Judgment Refinement/Amplification Techniques selected, although techniques have not been specified at this time (see discussion below). It is reasonable to assume that standard alphanumeric data entry techniques will be required. The use of interactive graphics, windowing, and speech synthesis/recognition techniques should also be considered.

3.4.6 HUMAN JUDGMENT REFINEMENT/AMPLIFICATION TECHNIQUES

The principal role of the human operator using a decision automation algorithm is to monitor the decisions and intercede when he identifies a decision which may be fundamentally incorrect. There are two possible ways in which the intercession may take place. First, the human may simply interrupt the algorithm processing to perform the remaining Engagement/Intercept Planning function by himself. Second, the human may interrupt the algorithm, inform it of the rejected decisions, and suggests alternate choices, allowing the algorithm to finish the planning function using its own procedures.

The second approach is preferable to the first for several reasons. The first is a simple human factors consideration. The human will be more reluctant to intercede if he msut assume the full workload from the algorithm, instead of making a few advisory inputs. Second, the first alternative would require the presence of a manual display/control back-up system similar to that currently used in the E-2C which would be used only for those occasions when the human decision maker assumes control over the algorithm. Finally, assuming the validity of the baseline assumption of this study (i.e., that in the 1985-2000 time frame the decision making requirements will overwhelm human capability), the human would, under the first alternative, be incapable of adequately performing the decision task he would be assuming.

The second approach described above requires that the imprecise and intuitive judgments of the human decision maker be input to the automation algorithm, translated and clarified to a form compatible with its own internal symbology, and then substituted for its own previously generated choices. These input, translation, clarification, and substitution sequences may require one or more techniques from the human judgment refinement/amplification portion of the technique taxonomy, but none of the methods listed are even vaguely appropriate for the task. This is not surprising, since decision automation is a much newer concept than decision aiding (although both are state-of-the-art approaches) and has not yet had sufficient time to develop a large inventory of specialized techniques peculiar to its needs.

In general, this has implications for the current effort. Where needed techniques do not exist, they must be developed. Interestingly enough, the precise techniques needed here cannot be identified until the decision automation algorithm is fully designed and implemented; methods to allow the input of the human decision maker to be incorporated into the "inner workings" of the decision algorithm cannot be created until these "inner workings" exist. Thus, while the need to develop new human judgment refinement/amplification techniques is seen as an eventual necessity, it can be postponed until a later stage in the automation algorithm development.

4. GENERALIZED ALGORITHM DESCRIPTION

4.1 APPROACH

The generalized Engagement/Intercept Planning algorithm described below is based on a merger of the decision methodology applied to the Engagement/Intercept Planning function (Section 3) and an understanding of AEW missions (Section 2).

The description presents the general outline and flow for the automation algorithm and introduces some of the concepts basic to its formulation. This generalized form will provide the framework for detailed algorithm development in the future. Some of the concepts and constructs used to describe the Engagement/Intercept Planning algorithm are listed in Section 4.2. Sections 4.3 and 4.4 present the generalized algorithm design. Section 4.3 describes the algorithm components necessary to execute the functional elements comprising the Planning function. Section 4.4 serves as a summary for the entire document, relating the functional elements to their associated algorithm components and automation techniques.

4.2 BASIC CONCEPTS AND CONSTRUCTS

The concepts and constructs listed here are introduced as a basis for the algorithm description which follows. They conform to two guidelines which were considered to be essential to the success of this effort. First, the algorithm should make no assumptions which limit its operational capability in the real world. While it is recognized that the Planning function in the AEW can be more abstract than the fighter's weapon control system, care must be taken to ensure tactical utility. Second, the algorithm must maintain sufficient flexibility to accommodate new data and models as they become available.

4.2.1 ALLOWANCE FOR BOGEY MANEUVER

In order to maintain realism, the algorithm should not assume that the enemy bogies will fly straight line flight paths. It should allow for bogey maneuver. Using track and intelligence data, it should be possible to compute the limits of possible bogey actions.

4.2.2 BUBBLE OF VULNERABILITY (BUVUL)

An important construct in the algorithm approach is the "Bubble of Vulnerability" for the task force. It provides the algorithm's predictive and analysis models with a means to determine whether a hostile target has reached a point where it can damage the task force. The BUVUL is defined as a three-dimensional smoothed surface which approximates the locus of bogey weapon-launched zones. The basic size and shape of the BUVUL will depend on the configuration of the ships in the task force and the nature of the bogey weapon systems deployed. In the multi-threat environment, the algorithm will work with a number of concentric BUVULS. The BUVUL should be defined so that horizontal cross-sections will result in circles, ellipses, or sets of superimposed circles.

4.2.3 CELL

The Engagement/Intercept Planning function algorithm must handle the multi-attack capability of the F-14/Phoenix weapon system and other similar systems. The concept of a cell was originated to fulfill this need. Assume a group of bogies flying in formation at a given range from a friendly multi-attack aircraft. It should then be possible to determine whether or not these bogies are flying inside a "cell" from which it would be impossible to evade a multiple attack. The boundaries of this cell can be calculated from knowledge of the friendly missile system, the range to the bogies, bogey aspect angle, bogey maneuverability, and the bogey track data. If there are a number of bogies inside a cell, the Engagement/Intercept Planning algorithm can handle them as one group; bogies lying outside a cell or in different cells will be considered separately.

4.2.4 FLAT EARTH

Computations incorporating the curvation of the earth require the use of more intricate distance and motion equations which need correspondingly larger amounts of computer processing time. In addition, the standard Navy terminology for describing position, namely, range, bearing, and altitude, tacitly ignores the earth's curvature. Therefore, a flat earth will be assumed for the algorithm unless it is operationally demonstrated that calculations based on this assumption are unsatisfactory.

4.3 ALGORITHM COMPONENTS FOR THE ENGAGEMENT/INTERCEPT PLANNING FUNCTION

The algorithm components comprise a system capable of executing the Engagement/Intercept Planning functions. The algorithm is pictured in Figure 4-1. The remainder of this section is devoted to an explanation of the individual components and their interrelationships.

4.3.1 COMMON VERSUS SPECIALIZED COMPONENTS

The algorithm components can be divided into two groups: those common to all AEW algorithms and those specialized for the Engagement/Intercept Planning function. The executive controller, the data base and its management facility, the display, the clock, the operator override interface, and the output to fighters/data link are items common to any AEW automation algorithm. The remaining components are those considered unique to the Engagement/Intercept Planning function.

4.3.2 GENERAL STRUCTURE

With the exception of the alerter, all the specialized components of the algorithm receive direction from the executive controller, exchange data with the data base management facility, and output their results to the display and/or the output data links. The alerter monitors the changing situation automatically while the operator monitors the functioning of the entire algorithm system.

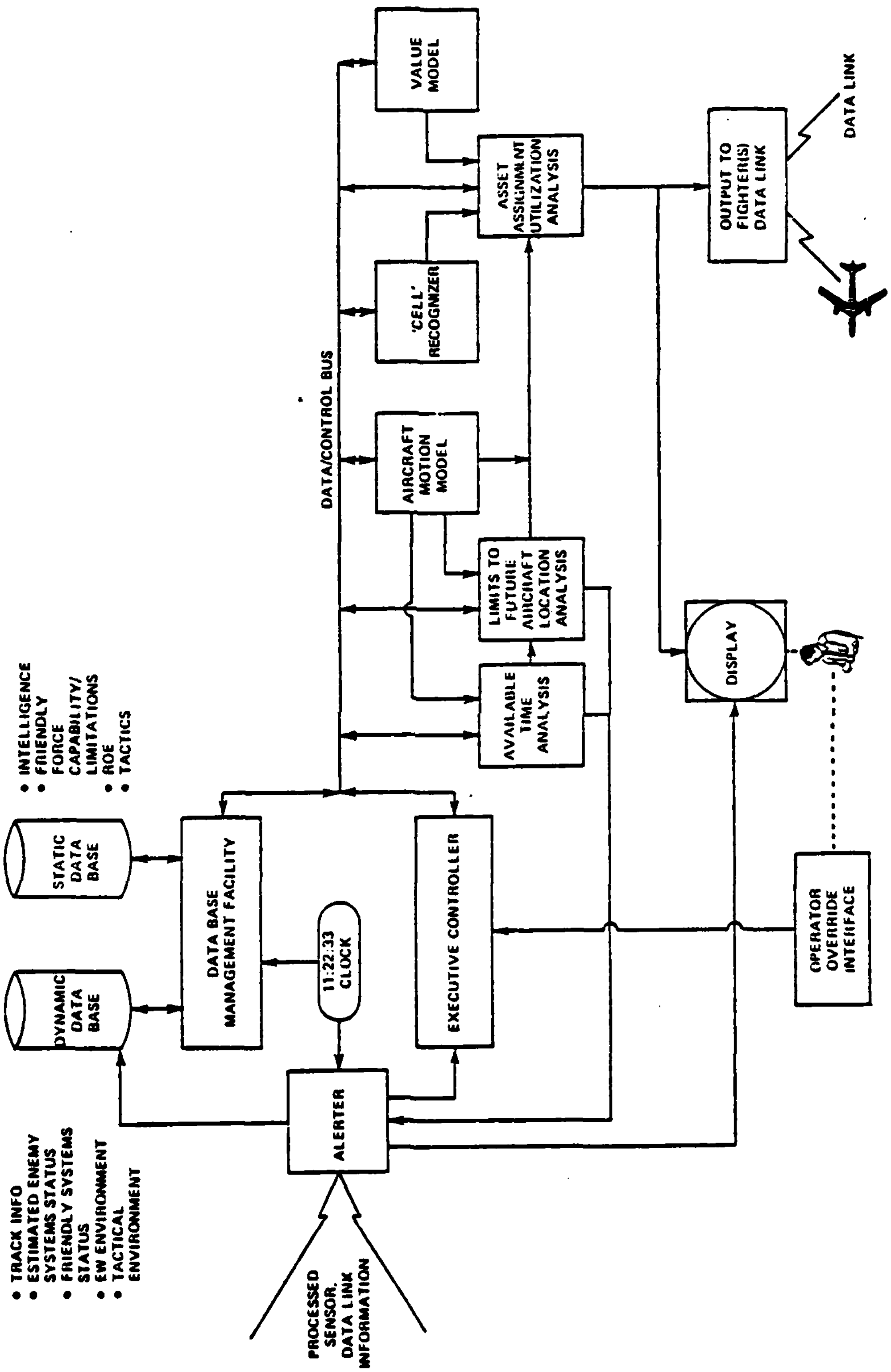


Figure 4-1. Generalized Engagement/Intercept Planning Algorithm

4.3.3 COMPONENT DESCRIPTION

The Executive Controller is a standard computer executive program which coordinates all the AEW decision algorithms (and possibly other functions as well). For the Engagement/Intercept Planning function, it will receive interrupts from the Alerter and the Operator Override Interface. These interrupts will then stimulate the Executive Controller to initiate a number of responses. The Executive Controller may inform the prediction or analysis models that new sensor input or operator-entered data is present for consideration. It may direct the algorithm to proceed to the next functional element, as is the case when time limits have expired before the resource allocation analysis has reached an optimal solution. Finally, it may redirect the processing flow to some starting point out of the normal operational sequence when the Alerter encounters radical changes in the data or when the Operator decides to exercise control.

The Alerter monitors the ongoing situation by filtering all new data entering the system. Any change in the situation which requires action will result in an interrupt to the Executive Controller and/or a displayed message to the Operator. In executing this task, the Alerter fulfills these roles. First, it alerts the Operator and the Executive Controller whenever any major friendly force system failure occurs, thereby allowing the Operator to intervene via the Operator Override Interface. Second, the Alerter acts as an auxiliary to the Executive Controller by applying the results of the Available Time Analysis. If the time limits established by the analysis are exceeded, the Executive Controller must be interrupted so that appropriate action can be taken. Third, the Alerter must inform the Execution Controller and the Operator of any unexpected data, such as new tracks, which might cause the normal processing flow to be redirected.

The Cell Recognizer is an artificial intelligence tool to recognize those data patterns which denote the existence of multiple attack possibilities. The existence of any cells is then input to the Asset Assignment/Utilization Analysis.

The Aircraft Motion Model which includes intercept tactic formulations is basic to the Engagement/Intercept Planning algorithm. From a knowledge of threat data and BUVUL location, the Aircraft Motion Model can be used to calculate the times required for each threat track to penetrate the BUVUL. The model is also used by the Limits on Future Aircraft Location Analysis and the Asset Assignment/Uitlization Analysis in performing their tasks.

The Available Time Analysis uses the results of the threat time to BUVUL calculations performed by the Aircraft Motion Model and parameter data on friendly force capability. The analysis will then determine the algorithm processing time constraints and decide if immediate action must be taken or whether there is time available to ascertain the "big picture". These time constraints are passed to the Alerter which can then interrupt the Executive Controller at the appropriate time.

Using Knowledge of the time constraints, intelligence data, and BLVUL location, the Limits to Future Aircraft Location Analysis estimates the boundaries of threatening enemy action. These boundaries are important to the Asset Assignment/Utilization Analysis and are also passed to the Alerter so that a change in threat status can be monitored.

The Value Model is necessary to evaluate the various solutions to the Engagement/Intercept Planning problem. The model will accomplish two of the functional elements: establishment of overall performance criteria at the outset of the Planning function and valuation of the individual intercept alternatives.

Overall performance criteria will be dependent on the task force's strategic position as conveyed to the AEW by the ROE's. In some scenarios, it may be important to minimize the risk to friendly fighters while planning the engagement. In other scenarios, defense of the task force must be pursued with little regard for the risks encountered by the assets under AEW control. To enable the Asset Assignment/Utilization Analysis to evaluate the solutions it generates in conjunction with the overall performance criteria, the Value Model must also supply means to valuate individual intercepts. For example, the Asset Assignment/Utilization Analysis might be told that intercepting an enemy bomber before it launches its two air-to-surface missiles (ASM) is worth twice the value of intercepting one of the missiles or three times the value of intercepting the same bomber after ASM launch.

The Asset Assignment/Utilization Analysis is the heart of the Engagement/Intercept Planning algorithm. All the previous analyses are combined in this component to actually produce target assignments, fighter positioning and vectoring, engagement timing, and other asset assignments. Due to the time criticality of the planning function, it is imperative that this analysis produce satisfactory, if not optimal, solutions. The outputs from the Asset Assignment/Utilization Analysis are sent both to the AEW Display and over the communications links to the appropriate friendly force combatants.

The Output to Fighter(s) Data Link component includes communication links to the fighters for intercept control, links to other airborne or shipboard assets under AEW control, and links to those ships controlling the AEW.

The Display serves the dual purpose of presenting to the human decision maker (Operator) rationale for and the results of the Engagement/Intercept Planning decision process, in addition to alerting him to any anomalous conditions.

The Operator Override Interface gives the Operator ultimate control over the decision making. He can use this control to remedy anomalous conditions or to initiate special tactics.

4.4 RELATIONSHIPS BETWEEN FUNCTIONAL ELEMENTS, DECISION AUTOMATION TECHNIQUES, AND ALGORITHM COMPONENTS

The relationships between the Engagement/Intercept Planning functional elements, the appropriate decision automation techniques, and the generalized algorithm components are summarized in Table 4-1. The functional elements listed in the left-hand column are originally derived from the high-level decision flow (Figure 3-2) and have a close correspondence with the Decision Variables, Relevant Analyses, and Required Human Judgments from the Function Description (Table 3-4). The appropriate decision technique categories for the functional elements are listed in the second column. In a number of cases, both Predictive and Analysis Techniques are required to accomplish one functional element. The specific techniques from each technique category which were selected by the matching process in Section 3.4 are shown in column three. The fourth column of the table contains the generalized algorithm components associated with the functional elements and appropriate techniques in the previous columns.* A brief description of the table entries, grouped by functional element, is presented below.

The Monitor Friendly Systems Status element is used to monitor friendly force status for system failures. This continuous analysis consists of status monitoring and alerting performed by the Alerter and the Display.

Cell Recognition of threat cells that can be handled by a multiple-attack fighter is an artificial intelligence pattern recognition technique handled by the Cell Recognizer component. Cell Recognition is an ongoing process that can be performed on the input threat track data soon after it enters the AEW decision algorithm system.

The Threat Time to BUVUL and Time Available Determination elements are used to answer the How Much Time question of Figure 3-2. Critical times which must be calculated are the time required for friendly force response and the time available to the algorithm for its optimal solution search.

Performance Criteria Selection must be accomplished by the Value Model component early in the formulation of the engagement/intercept plan.

The Time/Position Bounds on Enemy Action Determination performed by the Aircraft Motion Model and the Limits to Future Aircraft Location Analysis components is used to establish time and position bounds for enemy action.

Feasible Fighter Assignments with Fighter Vulnerability are made by the Predictive and Analysis Techniques incorporated in the Aircraft Motion Model, the Limits to Future Aircraft Motion Analysis, and the Asset Assignment/Utilization Analysis components.

Evaluation of the Feasible Fighter Assignments is provided by the Value Model.

*The Display has been omitted from the list of generalized algorithm components because it is common to all associated functional elements.

TABLE 4-1

Relationships Between Engagement/Intercept Planning Functional Elements Appropriate Decision Techniques and the Generalized Algorithm Components

FUNCTIONAL ELEMENT	APPROPRIATE TECHNIQUE CATEGORY(s)	APPROPRIATE SPECIFIC TECHNIQUE(s)	GENERALIZED ALGORITHM COMPONENT
MONITOR FRIENDLY SYSTEMS STATUS	ANALYSIS	STATUS MONITOR AND ALERT	ALERTER
CELL RECOGNITION	ANALYSIS	ARTIFICIAL INTELLIGENCE/PATTERN RECOGNITION	'CELL' RECOGNIZER
THREAT TIME TO BUVUL DETERMINATION	PREDICTIVE	DETERMINISTIC, PROBABALISTIC	A/C MOTION MODEL
TIME AVAILABLE DETERMINATION	ANALYSIS	INFORMATION PROCESSING	AVAILABLE TIME ANALYSIS
PERFORMANCE CRITERIA SELECTION	VALUE MODEL	MAUM NON-LINEAR UTILITY MODEL	VALUE MODEL
TIME/POSITION BOUNDS FOR ENEMY ACTION DETERMINATION	PREDICTIVE ANALYSIS	DETERMINISTIC, PROBABALISTIC ARTIFICIAL INTELLIGENCE	AIRCRAFT MOTION MODEL LIMITS TO FUTURE A/C LOCATION ANALYSIS
FEASIBLE FIGHTER ASSIGNMENTS WITH FIGHTER VULNERABILITY	PREDICTIVE ANALYSIS	DETERMINISTIC INFORMATION PROCESSING ARTIFICIAL INTELLIGENCE	A/C MOTION MODEL LIMITS TO FUTURE A/C LOCATION ANALYSIS ASSET ASSIGNMENT/ UTILIZATION ANALYSIS
EVALUATION OF FEASIBLE FIGHTER ASSIGNMENTS	VALUE MODEL	MAUM NON-LINEAR UTILITY MODEL	VALUE MODEL
FIGHTER/TARGET ASSIGNMENT WITH TACTIC SELECTION	ANALYSIS	LINEAR PROGRAMMING DYNAMIC PROGRAMMING ARTIFICIAL INTELLIGENCE/ HEURISTIC SEARCH	ASSET ASSIGNMENT/ UTILIZATION ANALYSIS
FIGHTER INTERCEPT TIMING, POSITIONING, AND/OR VECTORING	PREDICTIVE ANALYSIS	DETERMINISTIC, PROBABALISTIC INFORMATION PROCESSING ARTIFICIAL INTELLIGENCE	A/C MOTION MODEL ASSET ASSIGNMENT/ UTILIZATION ANALYSIS
BACKUP FORCES AND OTHER ASSET ASSIGNMENT	PREDICTIVE ANALYSIS	DETERMINISTIC LINEAR PROGRAMMING DYNAMIC PROGRAMMING ARTIFICIAL INTELLIGENCE/ HEURISTIC SEARCH	A/C MOTION MODEL ASSET ASSIGNMENT/ UTILIZATION ANALYSIS
IDENTIFICATION/RECTIFICATION OF ANOMALOUS SITUATIONS	HUMAN JUDGMENT	*	OPERATOR OVERRIDE
USE OF SPECIAL TACTICS	HUMAN JUDGMENT	*	OPERATOR OVERRIDE

* TECHNIQUES NOT SPECIFIED AT THIS TIME

The Fighter/Target Assignment with Tactic Selection element is performed by the optimization or artificial intelligence techniques comprising the Asset Assignment/Utilization Analysis component. This component then calls on the Aircraft Motion Model to compute the Fighter Intercept Timing, Positioning, and/or Vectoring. The Backup Forces and other Asset Assignment/Utilization Analysis components.

Anomalous Situation Rectification and Use of Special Tactics are Required Human Judgments which are exercised through the Operator Override Interface component.

5. CONCLUSIONS

An understanding of the AEW mission and the use of the decision situation methodology have resulted in the development of a generalized Engagement/Intercept Planning algorithm design. The generalized design will provide the framework for developing a prototype decision automation algorithm software design.

The next stage of the effort will entail the selection of algorithmic techniques and the development of detailed specifications for the identified algorithm components.

REFERENCES

(1) V/STOL-A Avionics Functional Description II

Volume II - Requirements Analysis

- T-60 to T-77, II-23 to 26
- Man Considerations, II-137ff

Volume III - Notional System Concepts

- System Processing, III-29ff
- Issues III 219ff

Volume IV - Functional Tree Block Diagrams

- Avionics Functional Hierarchy, IV-3ff
- Tactical Algorithm Computation, IV-37ff
- Display Control, IV-49ff
- Communications, IV-121ff
- Sensors, IV-136ff
- Countermeasures, IV-165ff

(2) V/STOL-A Functional Partitioning Effort

- Pages 4, 9, 10

(3) NATOPS Manual - E-2C

(4) Naval Warfare Publication 55 - 1-E2C

(5) Naval Warfare Publication 1 - Strategic Concepts of the U.S. Navy

(6) "Information Assessment for Airborne C^2, Analysis of Operator Decision Processes; Status Report 1: Problem Area Selection", Naval Air Development Center, Warminster, PA, 1979.

(7) Steen, Lynn A., "Linear Programming: Solid New Algorithm," Science News, Vol. 116, p. 235, October 6, 1979.

(8) Kolata, Gina B., "Mathematicians Amazed by Russian's Discovery," Science News, Vol. 206, No. 2, p. 545, November 2, 1979.

No. of Copies

Waddell, Sallie	1
Office of Naval Research London Branch Office Box 39, FPO New York, NY 09510	
Lawson, CDR Robert F., USN (RET)	1
Office of Naval Research Naval Applications Engineer Scientific Department 1030 E. Green Street Pasadena, CA 91106	
Bory, LTJG Alex	1
Pacific Missile Test Center (Code 1226) Point Mugu, CA 93042	
Holshauser, Ed	1
Pacific Missile Test Center (Code 1226) Point Mugu, CA 93042	
Jones, LCDR Tom	1
Pacific Missile Test Center (Code 1226) Point Mugu, CA 93042	
NAVAIRSYSCOM, AIR-950D	6
(4 for AIR-360B) (2 for retention)	
DTIC	2
NAVAIRDEVCEN	7
(R. Becker - 50A) . . . . 1 (L. Naglak - 502) . . . . 1 (C. Mattes - 5021) . . . . 1 (B. Svihel - 5023) . . . . 1 (J. Guarini - 20P5) . . . 1 (A. Greco - 7003) . . . . 1 (H. Beyer - 7012) 1	

	No. of Copies
Walchli, Richard Naval Air Test Center (SY 72) Patuxent River, MD 20670	1
Commander Naval Electronics Systems Command Washington, DC 20360	1
Ein, Robert J. Naval Electronics Systems Command (PME-107T) Washington, DC 20360	1
Rubenstein, Arnold Naval Material Command (Code NAVMAT 08T244) Crystal Plaza 5 Room 1044 Washington, DC 20360	1
Lewis, Warren Naval Ocean Systems Center (Code 8231) Human Engineering Branch San Diego, CA 92152	1
Silva, Dr. John Naval Ocean Systems Center (Code 823) San Diego, CA 92152	1
Regan, Dr. James J., Technical Director Naval Personnel Research and Development Center San Diego, CA 92152	1
Seymour, Dr. Harry R. Naval Personnel Research and Development Center Washington Liason Office Building 200, Wing 2N Washington Navy Yard Washington, DC 20374	1
Enderwick, Thomas, Commander Naval Personnel Research and Development Center Norfolk, VA 23511	1
Arima, Dr. Joseph Naval Post-Graduate School Monterey, CA 93940	1
Moroney, Bill LCDR Naval Post-Graduate School (Code 55MP) Monterey, CA 93940	1
Poock, Gary Naval Post-Graduate School (Code 55PK) Monterey, CA 93940	1

	No. of Copies
Gibson, CDR Richard S. . . . . Bureau of Medicine and Surgery, Navy Department Head, Aerospace Psychology Branch (Code 513) Washington, DC 20372	1
Nelson, CAPT Paul D. . . . . Bureau of Medicine and Surgery, Navy Department Head, Medical Services Corps Washington, DC 20372	1
Gallagher, CAPT Thomas, MSC, USN . . . . Naval Aerospace Medical Research Laboratory Aerospace Psychology Department Pensacola, FL 32508	1
Goodson, CAPT J. . . . . Naval Aerospace Medical Research Laboratory Aerospace Psychology Department (Code L53) Pensacola, FL 32508	1
Waldeisen, CDR. Lewis . . . . Naval Aerospace Medical Research Laboratory Aerospace Psychology Department Pensacola, FL 32508	1
Bittner, Dr. Alva . . . . Naval Aerospace Medical Research Laboratory Detachment New Orleans, LA 70189	1
Kennedy, Robert S., CDR, MSC, USN . . . . Naval Aerospace Medical Research Laboratory Detachment Box 29407 New Orleans, LA 70189	1
Hutchins, CDR C. W. . . . . Naval Air Systems Command (Code AIR-340F) Washington, DC 20361	1
Jasper, CAPT C. R. . . . . Naval Air Systems Command (Code AIR-413) Washington, DC 20361	1
Schiflett, Sam . . . . Naval Air Test Center (Code SY721) Patuxent River, MD 20670	1
Gregoire, CDR Harvey . . . . Naval Air Test Center (SETD Code SY 70) Patuxent River, MD 20670	1

	No. of Copies
Shannon, LCDR Richard H. Naval Safety Center (Code 12) NAS Norfolk, VA 23511	1
Andrews, Phil J. Naval Sea Systems Command (Code 61R2) Crystal Plaza 6 Room 880 Washington, DC 20362	1
Breaux, Dr. Robert Naval Training Equipment Center (Code N-711) Orlando, FL 32813	1
Funaro, CDR Joseph Naval Training Equipment Center (N-8) Orlando, FL 32813	1
Harvey, Dr. J., Technical Director Naval Training Equipment Center (00TD) Orlando, FL 32813	1
Erickson, Ronald A. Naval Weapons Center (Code 3175) China Lake, CA 93555	1
Wagner, Dan Naval Weapons Center China Lake, CA 93555	1
Denicoff, Marv Office of Naval Research (Code 437) 800 N. Quincy Street Arlington, VA 22217	1
Malecki, Gerald S. Office of Naval Research (Code 455) 800 N. Quincy Street Arlington, VA 22217	1
O'Hare, Dr. John J., Assistant Director, Engineering Psychology Program 800 N. Quincy Street Arlington, VA 22217	1
Tolcott, Dr. Martin Office of Naval Research (Code 455) 800 N. Quincy Street Arlington, VA 22217	1

DISTRIBUTION LIST

REPORT NO. NADC-80104-50

AIRTASK NO. 3600000/001B/9F21-200-000
AIRTASK NO. A035-3400/001B/WF57-525-000

	No. of Copies
Fossum, Dr. Robert R., Director Defense Advanced Research Projects Agency 1400 Wilson Blvd. Arlington, VA 22209	1
Fletcher, Dr. Dexter Defense Advanced Research Projects Agency Cybernetics Technology Office 1400 Wilson Blvd. Arlington, VA 22209	1
Chatelier, CDR Paul R. Assistant for Training and Personnel Systems Technology Office of the Under Secretary of Defense Research & Engineering (R&AT) The Pentagon Washington, DC 20301	1
Snavely, Mary M. Deputy Assistant Secretary of the Navy (Manpower) Office of the Assistant Secretary of the Navy (Manpower) The Pentagon Room 4E789 Washington, DC 20350	1
Mann, David E. Office of the Assistant Secretary of the Navy Research, Engineering and Systems The Pentagon Room 4E736 Washington, DC 20350	1
Fulkerson, CDR Grant D. Office of the Chief of Naval Operations Code OP-112C The Pentagon Arlington Annex 2613 Washington, DC 20370	1
Malehorn, Merlin K. Office of the Chief of Naval Operations Head, Research, Development & Studies Branch (Code OP-102) The Pentagon Washington, DC 20350	1
Smith, Dr. Robert Office of the Chief of Naval Operations Code OP-987H The Pentagon Room 50772 Washington, DC 20350	1

FI

O